

Claims

- [c1] A multi-channel laser interferometric method for measuring the displacement of a surface of a material subjected to ultrasound, which comprises :
- generating a laser beam having a predetermined intensity;
 - dividing the laser beam into a reference beam and a probe beam having respective intensities representing minor and major fractions of the predetermined intensity;
 - passing the probe beam through an optical lens to focalize the probe beam onto the surface of the material subjected to ultrasound, thereby scattering same;
 - expanding the reference beam;
 - combining the scattered probe beam collected by said optical lens with said expanded reference beam to obtain an optical fringe signal;
 - receiving said optical fringe signal on at least one array of photodetectors, wherein said optical fringe signal fully covers said array and each photodetector of the array defines a channel, having a given aperture smaller than the aperture of said optical lens to receive a portion of said optical fringe signal and converting said portion of said optical fringe signal into an electrical signal;
 - processing for each channel said electrical signals through circuitry means;
 - summing electrically said processed signals to extract an output signal correlated to the motion of said surface.
- [c2] A method according to claim 1, wherein processing comprises first filtering said signals, then squaring said filtered signals.
- [c3] A method according to claim 1, wherein processing comprises first filtering said signals, then rectifying said filtered signals.
- [c4] A method according to claim 1, wherein it further comprises:

- linearly polarizing the scattered probe beam collected by the optical lens, circularly polarizing the expanded reference beam;
- combining the linearly polarized scattered probe beam with the circularly polarized expanded reference beam to obtain two optical fringe signals having a phase shift of 90° ;
- receiving the first and second optical fringe signals on two arrays of detectors, the two arrays of detectors being identical, two detectors of the corresponding channels of the arrays generating two in-quadrature electrical signals, the electrical signal pairs being then processed together through said circuitry means.

[c5] A method according to claim 4, wherein the step of processing comprises :

- first dividing and filtering said in-quadrature signal pairs to separate each signal into a high-frequency signal and a low-frequency signal, then for each signal pair,
- Generating two signals by cross-multiplication between the said low-frequency signal pair and the said high-frequency signal pair,
- differentiating the said two signals.

[c6] A method according to claim 4, wherein the step of processing comprises :

- first dividing and processing said in-quadrature signal pairs to separate each signal into the original signal and its derivative signal, then for each signal pair,
- Generating two signals by cross-multiplication between the said original signal pair and the said derivative signal pair,
- differentiating the said two signals.

[c7] A method according to claim 4, wherein the step of processing comprises :

- first high-pass filtering said signal pairs, then for each signal pair,
- summing the two signals obtained by squaring of each signal of the signal pair.

[c8] A method according to claim 4, wherein the step of processing comprises :

- first high-pass filtering said signal pairs, then for each signal pair,
- summing the two signals obtained by rectification of each signal of the signal pair.

[c9] A method as claimed in claim 1, wherein said scattered probe beam and said expanded reference beam having crossed polarization, it further comprises dividing each of the scattered probe beam and the expanded reference beam in two optical signals having a 180° phase difference, the combining of the optical signals resulting in four optical fringe signals having -90° , 0° , 90° and 180° relative phase differences; and wherein the step of receiving further comprises:

- receiving the four optical fringe signals on four arrays of detectors, the four arrays of detectors being identical, each set of four detectors of a corresponding channel generating two in-quadrature pairs of out-of-phase electrical signals,
- subtracting each said out-of-phase electrical signals to obtain a pair of differential in-quadrature electrical signals for each said channel, said pairs of differential in-quadrature electrical signals being processed together through said circuitry means.

[c10] A method as claimed in claim 1, wherein it further comprises :

- frequency shifting said reference beam, the optical fringe signal resulting from combining said scattered probe beam with said expanded shifted reference beam being an heterodyne optical fringe signal, and
- the step of processing comprising demodulating each electrical signal for each channel by removing the frequency shift using heterodyne demodulation techniques.

[c11] A multi-channel laser interferometric apparatus for measuring the motion of a surface of a material subjected to ultrasound, which comprises:

- a laser source for generating a laser beam having a predetermined intensity;

- a beam splitter for dividing said laser beam into a reference beam and a probe beam having respective intensities representing minor and major fractions of said predetermined intensity;
- an optical lens disposed for focalizing said probe beam onto the surface of said material subjected to ultrasound, thereby scattering same;
- a beam expander expanding said reference beam;
- combining means for combining the scattered probe beam with said expanded reference beam to obtain an optical fringe signal;
- receiving means with at least one array of detectors for receiving said optical fringe signal on, wherein the optical fringe signal fully covers the array, and each detector, defining a channel, has a given aperture smaller than the aperture of said optical lens to receive a portion of said optical fringe signal and convert said portion of said optical fringe signal into an electrical signal;
- circuitry means for processing for each channel said electrical signals and summing said processed signals to extract an output signal correlated to motion of the surface.

[c12] An apparatus according to claim 11, wherein circuitry means comprise filtering means for filtering the electrical signals and squaring means for squaring the filtered signals.

[c13] An apparatus according to claim 11, wherein circuitry means comprise filtering means for filtering the electrical signals and rectifying means for rectifying the filtered signals.

[c14] An apparatus according to claim 11 further comprising polarizing means for circularly polarizing the expanded reference beam, wherein:

- the combining means comprise a polarizing beam splitter for combining the linearly polarized scattered probe beam with the expanded circularly polarized reference beam to obtain two optical fringe signals having a phase shift of 90° ;

- the receiving means comprise two identical arrays of detectors for receiving the optical fringe signals on, the two detectors of a same channel of each array generating a pair of in-quadrature electrical signals, the pairs of in-quadrature electrical signals being then processed together by the circuitry means.

[c15] An apparatus according to claim 11, wherein it further comprises:

- polarizing means for setting the polarization of the expanded reference beam orthogonal to the polarization of the probe beam;
- dividing means to divide each of the polarized scattered probe beam and the expanded orthogonally polarized reference beam into a first and a second signals;
- an optical retardation device in one of the first or second optical signals to obtain a phase shift of 90° between the first and second optical signals; and wherein :
- the combining means comprise two polarized beam splitters for combining the two orthogonally polarized components of the first and second optical signals, each into two optical fringe signals having a 180° phase difference; resulting in four optical fringe signals having -90° , 0° , 90° and 180° relative phase differences;
- the receiving means comprise four identical arrays of detectors for receiving the four optical fringe signals, each set of four detectors of a corresponding channel generating two pairs of out-of-phase electrical signals,
- the circuitry means further comprise subtracting means for subtracting each of the out-of-phase electrical signals to obtain a pair of differential in-quadrature electrical signals for each said channel, the pairs of differential in-quadrature electrical signals being then processed together.

[c16] A multi-channel laser heterodyne interferometric apparatus according to claim 11, wherein it further comprises a frequency shifting device for frequency

shifting the reference beam by a given frequency, the frequency shifted reference being then expanded, and wherein :

- the combining means combine the scattered probe beam with the expanded frequency shifted reference beam to obtain an heterodyne optical fringe signal, the heterodyne optical fringe signal being received by the receiving means;
- the circuitry means comprise demodulation means for processing for each channel the heterodyne electrical signals through demodulation by removing the frequency shift using standard heterodyne demodulation techniques, the output signal obtained by summing the processed signals being proportional to the displacement of the surface.

[c17] An apparatus according to claim 11, wherein the array of detectors is a linear array of detectors.

[c18] An apparatus according to claim 11, wherein the array of detectors is a two-dimensional array of detectors

[c19] A multi-channel fiberized laser interferometric apparatus according to claim 11, wherein it further comprises a multi-mode optical fiber and coupling means for coupling the laser beam into the optical fiber, and wherein :

- a partially reflecting coating at the optical fiber end enables dividing the laser beam into the reference beam and the probe beam;
- the optical lens for focalizing the probe beam onto the surface of the material is disposed at the end of the optical fiber, and refocuses the scattered probe beam into the optical fiber;
- the receiving means comprise at least one two-dimensional array of detectors and a second optical lens for focusing on the array of detectors the multi-mode optical beam exiting through the entrance face of the multi-mode fiber and corresponding to the mixing between the scattered beam and the partially reflected beam.